5-1988

Effects of BAK and CHG on deposit formation with rigid gas permeable lenses

Cherrie Christner
Pacific University

Robert Kearns
Pacific University

Ami Patel
Pacific University

Effects of BAK and CHG on deposit formation with rigid gas permeable lenses

Abstract

This study evaluated the effect of Benzalkonium Chloride and Chlorhexidine on deposit formation with Paraperm EW and Ocusil RGP lenses. In a double blind study, seventeen first time RGP patients were fit with one Paraperm EW lens, which has a negative surface charge, and one Ocusil lens, which has a neutral surface charge. The lenses were measured for transmissibility prior to dispensing. Half of the patients used solutions preserved with BAK. The other half used solutions preserved with CHG. After two months the lenses were measured for transmissibility. The patients were then dispensed a new pair of lenses so that each lens material was worn on alternate eyes. They were also given the alternate lens care solutions. At the end of two months the lenses were measured for transmissibility. A comparison was made between the two lens care solutions and between the two lens materials. No significant difference was found in light transmissibility between the two lens care solutions or between the two lens materials. This implies that there was no difference in deposit formation between the two lens care solutions or between the two lens materials. Therefore, while the electrostatic binding theory of deposit formation may be correct, deposit formation does not reach a level which is clinically significant.

Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Jack Roggenkamp

Keywords

rigid gas permeable lenses, benzalkonium chloride, chlorhexidine gluconate, deposit formation, electrostatic surface charges

Subject Categories

Optometry

EFFECTS OF BAK AND CHG ON DEPOSIT FORMATION

WITH RIGID GAS PERMEABLE LENSES.

BY

CHERRIE CHRISTNER

ROBERT KEARNS

AMI PATEL

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
for the degree of
Doctor of Optometry
May, 1988

Adviser:

Jack Roggenkamp, O.D.

SIGNATURE PAGE

Cherrie Christner
CHERRIE CHRISTNER

Robert Kearns
ROBERT KEARNS

Ami Patel
AMI PATEL

JACK ROGGENKAMP, OD

ABSTRACT

This study evaluated the effect of Benzalkonium Chloride and Chlorhexidine on deposit formation with Paraperm EW and Ocusil RGP lenses. In a double blind study, seventeen first time RGP patients were fit with one Paraperm EW lens, which has a negative surface charge, and one Ocusil lens, which has a neutral surface charge. The lenses were measured for transmissibility prior to dispensing. Half of the patients used solutions preserved with BAK. The other half used solutions preserved with CHG. After two months the lenses were measured for transmissibility. The patients were then dispensed a new pair of lenses so that each lens material was worn on alternate eyes. They were also given the alternate lens care solutions. At the end of two months the lenses were measured for transmissibility. A comparison was made between the two lens care solutions and between the two lens materials. No significant difference was found in light transmissibility between the two lens care solutions or between the two lens materials. This implies that there was no difference in deposit formation between the two lens care solutions or between the two lens materials. Therefore, while the electrostatic binding theory of deposit formation may be correct, deposit formation does not reach a level which is clinically significant.

KEY WORDS

Rigid Gas Permeable Lenses
Benzalkonium Chloride
Chlorhexidine Gluconate
Deposit Formation
Electrostatic Surface Charges

ACKNOWLEDGEMENTS

We gratefully acknowledge the following companies/institutions for their contributions to our thesis:

Allergan Optical, 2525 Dupont Drive, Irvine, CA 92715, for supplying us with LC 65 Cleaning solution and Wet-N-Soak Wetting and Soaking solution.

Opti-Con, 725 NE 102nd, Portland, OR 97220 for supplying us with Paraperm EW and Ocusil lenses.

Pacific University Chemistry Department, Forest Grove, OR for the use of their spectrophotometer.

Polymer Technology Corp., 100 Research Drive, Wilmington, MA 01887 for supplying us with Boston Cleaning and Conditioning solutions.

Partial support for this work was provided by the National Science Foundation's College Science Instrumentation Program through grant #CSI-8650463.

ABOUT THE AUTHORS

Cherrie Christner will be graduating from Pacific University College of Optometry in May, 1988 with an OD degree. She obtained her BS in Biology from Colorado College in 1982. Originally from Lookout Mountain, CO, she plans to reside and practice optometry in Colorado.

Robert Kearns will be graduating from Pacific University College of Optometry with an OD degree in May 1988. He earned his BS in Visual Science from Pacific University in December, 1986. Orignally from Northern California, he plans to reside on the west coast.

Ami Patel will be graduating from Pacific University College of Optometry with an OD degree in May 1988. She earned her BS in Visual Science from Pacific University in December, 1986. Originally from Nairobi, Kenya, she plans to make her home and practice optometry in Southern California.

INTRODUCTION

Silicone acrylate rigid gas permeable (RGP) lenses have become very popular in recent years due to their high oxygen permeability. However, the increased oxygen permeability of these lenses is limited by the hydrophobic nature of silicone which impairs the lens surface wettability. [1,2] In addition, when a typical silicone acrylate lens is immersed in an aqueous solution, it undergoes ionization. In this process, hydrogen atoms are released from hydroxyl groups, thus creating a number of negatively charged sites on the lens surface. [3] These charged sites are then free to electrostatically bind with any cationic ion and thereby increase the lens' affinity for deposits. This problem was only complicated when an attempt was made to counteract the hydrophobicity of the silicone content of the lens by incorporating wetting monomers, such as methacrylic acid (MAA), into the lens polymer. MAA is negatively charged and therefore increases the overall electronegativity of the lens surface, thus strengthening the adherence of proteins, lysozyme, and other positively charged particles. [1,3]

The tendency for silicone acrylate lenses to bind hydrophobic molecules when dry and positively charged particles when wet, has led to a controversy as to whether lens solutions which are preserved with Benzalkonium Chloride (BAK) should be used with RGP lenses. BAK is a quartenary ammonium compound which consists of a long hydrophobic tail and a positive charge located at the nitrogen site. It is therefore, theoretically possible for BAK to partially and irreversibly bind to the lens surface. [2] In fact, BAK has been reported to destabilize the lipid layer of the tear film, reduce lens surface wettability, and increase lens deposits. [4,5]

Several studies have arisen out of this controversy. Rosenthal, et al compared the uptake of BAK and Chlorhexidine Gluconate (CHG) by Boston II, Paraperm O2, and PMMA lenses. They found that uptake of CHG reached a plateau on day four and increased very little after that. BAK on the other hand, continued to be absorbed up until the termination of the study at day 20. The proposed mechanism of absorption for CHG is that the positively charged molecules bind to free carboxylate groups on the lens surface by electrostatic attraction. [6,7] CHG molecules have a positive charge on both ends and therefore resist self aggregation. [3] Consequently, once the anionic binding sites of the lens have become saturated, no further CHG uptake occurs. Likewise, BAK binds via electrostatic forces. However, its longer hydrophobic chains can bind to each other via hydrophobic interactions thus creating a layering effect. It therefore has the potential to build up to toxic concentrations. It also increases the hydrophobicity of the lens surface, which decreases the wettability and thereby promotes the formation of deposits. In addition, Rosenthal, et al found that neither the Boston cleaner nor LC65 was effective in removing BAK or CHG from the surface of the lenses. [6,7]

Wong, et al, on the other hand, studied BAK absorption on RGP lenses and found that 0.6 micrograms of BAK could be expected to absorb on Boston II lenses. Since two drops of a .02% bacteriostatic preparation of BAK would deliver 20 ug of BAK to the cornea, they argue that 0.6 ug will not create any clinical problems. [8] They also found that BAK uptake plateaus between the 5th and 15th day, and therefore feel that BAK absorption is limited and will not reach toxic levels. In addition, they found that less BAK was absorbed by the lenses in their in vivo study then in their in vitro study and believe the difference is due to the daily cleaning regimen that the patients performed in the in vivo study. They argue, therefore, that any appreciable amount of preservative absorbed onto the lens can be easily removed with a daily cleaner. [5] Finally, they found no loss of wettability among the lenses after exposure to BAK. [8]

Several other studies conducted in this area include: Huth et al, Meakin and Gee, Hoffman, Richardson et al, and Dziabo et al. Huth et al studied BAK uptake by Boston and Polycon lenses. They found that the absorption of BAK by these lenses was negligible.[9] Meakin studied BAK absorption by Boston and PMMA lenses. He found very little BAK absorption and found that the Boston lens absorbed no more than the PMMA.[10] Hoffman reported on the uptake and release of BAK from Optacryl K and EXT lenses. He found no significant difference between the two lenses. He also found that the Optacryl lenses absorbed less than PMMA lenses.[11] Richardson, et al found that CAB lenses absorbed less BAK than PMMA lenses.[12] Finally, Dziabo, et al studied the effect of BAK, CHG and thimerisal on the wettability of Polycon II, Boston II, Boston IV, Paraperm O_2 Plus and Optacryl K lenses. They found no loss in wettability as a result of the preservatives. [13]

Since most of the above studies were relatively short term in vitro studies, we decided to perform a longer term in vivo study comparing the effect of BAK and CHG on the development of deposits by Paraperm EW and Ocusil lenses. We also compared the difference in deposit buildup between the Paraperm EW lens which has a negative surface charge and the Ocusil lens which has a neutral surface charge to determine whether the electrostatic binding theory can account for the difference in deposit buildup. We performed a double blind experiment in which the experimental subjects served as their own control. Assuming the electrostatic binding theory of deposit formation is correct, we proposed that the Paraperm EW lens would develop significantly more deposits, as measured by a decrease in light transmissibility, than the Ocusil lens. We also proposed that the solutions preserved with BAK would lead to more deposit formation than the solutions preserved with CHG.

METHOD

Seventeen (17) first time RGP subjects, between the ages of 15 and 40, were randomly selected from the patient population of the Pacific University College of Optometry. All the subjects had refractive errors between 6.0 diopters of myopia and 3.0 diopters of hyperopia with less than 1.5 diopters of corneal astigmatism. None of the subjects had ocular pathologies and no presbyopes were included in the study.

The subjects were fit with two identical pairs of contact lenses by fourth year interns in the general clinic of Pacific University College of Optometry. One pair was made from the Paraperm EW material, Paragon Optical, and other pair made from the Ocusil material, International Hydron/Oculus.

The lenses were cleaned with two drops of Boston Daily Cleaner, Polymer Technology, rinsed with tap water and then mounted in a dry cell using a cardboard insert with double backed tape. Pre-dispense measurements of transmissibility were taken using the Varian OMS 200 UV Visible Spectrophotometer. The lenses were scanned in the visible spectrum range between 290 nm and 700 nm. The data was then printed in the form of a graph with wavelength (290 nm - 700 nm) plotted as the abscissa and percent transmisssion poltted as the ordinate.

A pair of lenses consisting of one Paraperm EW lens and one Ocusil lens, were then dispensed to the subjects as a double blind experiment. Neither the interns nor the subjects knew which material was being worn on each eye. The subject was arbitrarily assigned either the Boston Cleaning and Conditioning solutions, Polymer Technology, or LC 65 Cleaner and Wet-N-Soak Wetting and Soaking Solution, Allergan. The subjects were instructed to use these solutions according to the solution manufacturer's recommendations. The lenses were then worn for approximately two months at which time the lenses were retrieved and remeasured for transmissibility using the spectrophotometer in the procedure as described above. The second set of lenses, which also had baseline measurements taken on them, were then dispensed, so that now each lens material was being worn on the alternate eye. The subjects were also given the alternate lens care solutions at this time. Again the lenses were worn for approximately two months. The lenses were then retrieved and measured for transmissibility using the spectrophotometer as described above.

The transmissibility of each lens following the two month wearing period was compared to the baseline transmissibility of that lens. The difference in transmissibility of the Paraperm EW lens, which was soaked in a given solution, was then compared to the difference in transmissibility of the Ocusil lens, which had been soaked in that same solution. A two tailed t-test at the .05 level of significance was performed to see if there was a significant difference in deposit buildup between the two lens materials as measured by a decrease in transmissibility. Likewise, the difference in transmissibility of a given lens material which had been used in combination with the solutions preserved with BAK, was compared to the difference in transmissibility of the same lens material which had been used in combination with the solutions preserved with CHG. A two-tailed t-test was performed to determine if there was a significant difference in deposit buildup between the two solutions, as measured by a decrease in transmissibility.

The experimental group served as its own control. Since both solutions and both lens materials were used on each eye, differences in tear makeup and quality of tear film between the two eyes did not affect our study. Also, since the two lens materials were being studied simultaneously within a given subject and since the two solutions were being compared within a given subject, poor lens care compliance did not affect our study. In addition, at any given time, 50% of the lenses being worn were Paraperm EW and 50% of the lenses being worn were Ocusil. Also, at any given time, 50% of the patients were using the Boston solutions and 50% of the patients were using the Allergan solutions. Therefore, environmental variations should not have affected our study. Finally, the comparisons being made were made for a given subject and variations between the subjects would not affect the results.

RESULTS

We randomly selected five wavelengths from the spectrum between 290nm-700nm, and decided to examine the data at those points. We selected 372 nm, 454 nm, 618 nm and 700 nm. Table 1 shows the difference in transmissibility of the lenses used in conjunction with Wet-N-Soak from baseline and the difference in transmissibility of the lenses used in conjunction with Boston from baseline. It also shows the difference in transmissibility of the Ocusil lenses from baseline and the difference in transmissibility of the Paraperm EW lenses from baseline at 372 nm. Tables 2-5 give the same information at the wavelengths of 454 nm, 536 nm, 618 nm and 700 nm respectively. A negative number indicates that there was a relative decrease in transmission from baseline. A positive number indicates a relative increase in transmission. The data was examined as a whole, and a relative increase in transmissibility following the two month wearing period was revealed in all four cases. In general, Boston produced a greater increase in transmissibility than did Wet-N-Soak. Likewise, the Paraperm EW lenses showed a greater increase in transmission than the Ocusil lenses. These facts are illustrated by the bar graphs in Figs. 1 and 2. In addition, the percentiles plot in Fig. 3 illustrates that the lenses used in conjunction with Boston showed a consistently higher transmission reading than the lenses used in conjunction with Wet-N-Soak. Whereas Fig. 4 illustrates that the Paraperm EW lenses did not show a consistently higher transmission reading than the Ocusil lenses.

We compared the lenses used in conjunction with Wet-N-Soak to those used in conjunction with Boston using a paired t-test at the .05 level of significance. We found the following probabilities: 372 nm (.5393), 454 nm (.4639), 536 nm (.4251), 618 nm (.4465) and at 700 nm (.3759). This indicates that there was no significant difference in transmissibility between the lenses used in conjunction with Wet-N-Soak and the lenses used in conjunction with Boston.

We also compared the Ocusil lenses to the Paraperm EW lenses using a paired t-test at the .05 level of significance. We found the following probabilities: 372 nm (.7921), 454 nm (.8345), 536 nm (.9819), 618 nm (.9818), and at 700 nm (.8396). This data is also illustrated in Tables 6-10. This indicates that there was no significant difference in transmissibility at wavelengths 372 nm, 454 nm, and 700 nm. There was a significant difference in transmissibility at the wavelengths of 536 nm and 618 nm. However, this indicates a significant increase in transmissibility and therefore does not imply that deposit formation has taken place. We anticipated a decrease in transmissibility as a result of deposit formation. At 536 nm Paraperm EW lenses showed a significant increase in transmissibility over the Ocusil lenses, and at 618 nm, Ocusil lenses showed a significant increase in transmissibility over the Paraperm EW lenses. So one lens material was not consistently better than the other. However, overall Paraperm EW lenses showed a greater increase in transmission than did the Ocusil lenses.

DISCUSSION

The results of this study showed that there was no significant difference at the .05 level of significance in the amount of deposit formation, as measured by a decrease in transmissibility, between the solutions preseved with BAK and the solutions preserved with CHG. There was also no significant difference between the Paraperm EW lenses and the Ocusil lenses in the amount of deposit formation, as measured by a decrease in transmissibility. This implies that the electrostatic binding theory of deposit formation, discussed in the introduction, cannot account for a difference in deposit formation. These results support those of Wong, et al, Huth et al, Meakin, Hoffman, Richardson and Dziabo et al. So cumulative experimental data indicates that although deposit formation takes place with solutions containing BAK, it is negligible in amount and is not significantly different from the deposit formation that takes place with solutions containing other preservatives. Therefore, practitioners should feel comfortable dispensing any of the currently available solutions for the care of their patient's RGP lenses, since the type of preservative does not affect the amount of deposit formation.

The fact that we actually found an increase in transmission following contact lens wear perplexes us. The only possible explanation that we can offer for this finding is that the lenses were in a relatively dehydrated state when the baseline measurements were taken and they were in a relatively hydrated state when the post measurements were taken. This is due to the fact that the manufacturer sent the lenses dry and care was not taken to hydrate the lenses prior to our pre-dispense measurements.

The results of this study have several limitations. The first is the small sample size. Several subjects had to be dropped from the study due to adverse reactions to the solutions. There was a 50/50 split as to which solution the subjects reacted to, and therefore no inference can be made as to the antigenicity of the preservatives. The study was also limited by the range of wavelengths which we scanned. We scanned in the visible spectrum between 290 nm and 700 nm. Information that we received late in our study indicated that protein deposit formation would be reflected by a decrease in transmissibility in the range of wavelengths between 800 nm and 2000 nm. [14,15,16] Finally, no subjective information was gathered. Additional information could be gathered if the patients were asked for their subjective comments about the comfort of the lenses and if a subjective measurement of deposit formation was performed concurrently with the transmissiblility study.

REFERENCES

1. Seidner L. Wettability Vs Surface Deposits: Searching for a Solution. Contact Lens Forum 1987 Oct:50-52.

2. Bennett E, Ghromley R. Rigid Extended Wear: An Overview. ICLC 1897 Aug; 14(8):319-331.

3. Herskowitz R. Solution Interaction and Gas-Permeable Lens Performance. The Contact Lens Journal 1987 Feb; 58(11):3-8.

4. Hopkins GA. The Formulation of Rigid Lens Care Systems. Optician 1986 Mar:18-22.

5. Wong MP, Dziabo AJ, Kiral RM. Dynamics of BAK Absorption by Silicone Acrylate Lenses. Contact Lens Spectrum 1986 Nov:49-53.

6. Rosenthal P, Chou MH, Salamohe JC, Israel SC. Preservative Interaction with RGP Lenses. Optician 1986 Dec:33-38.

7. Rosenthal P, Chou MH, Salamohe JC, Israel SC. Quantitative Analysis of Chlorhexadine Gluconate and Benzalkonium Chloride Absorption on Silicone/Acrylate Polymers. CLAO Journal 1986 Jan; 12(1):43-50.

8. Wong MP, Dziabo AJ, Kiral RM. Absorption of Benzalkonium Chloride by RGP lenses. Contact Lens Forum 1986 May:43-50.

9. Huth S, Cohn L, Eriksen S. Care Products for Silicone-Copolymer Lens Materials. Optician 1981 Aug:16-18.

10. Walters KA, Gee HJ, Meakin BJ. The Interaction of Benzalkonium Chloride with Boston Contact Lens Material. J. Brit. Contact Lens Assoc. 1983 6(2):42-50

11. Hoffman WC. Ending the BAK-RGP Controversy. ICLC 1987 Jan; 14(1):31-35.

12. Richardson NE, Gee HJ, Meakin BJ. The Compatibility of Benzalkonium Chloride with CAB Lens Material. J. Brit. Contact Lens Assoc. 1980 3(3):120-124.

13. Dziabo AJ, Hall M, Kiral RM, Rich WJ. Preservative Effects on the Wettability of Rigid Gas Permeable Lenses. ICLC 1987 Feb; 14(2):62-66.

14. Castillo EJ, Koenig JL, Anderson JM. Characterization of Protein Adsorption on Soft Contact Lenses. Biomaterials 1986 March; 7:93-95.

15. Castillo EJ, Koenig JL, Anderson JM. Surface Analysis of Biomedical Polymers by Attenuated Total Reflectance-Fourier Transform Infra-Red. Biomaterials 1984 July; 5:186-192.

16. Hosaka S, et al. Analysis of Deposits on High Water Content Contact Lenses. Journal of Biomedical Materials Research 1983; 17:261-274.

372 nm

	w & s	boston	ocusil	paraperm
1	1.1	2.0	2.3	1.1
2	2.3	.8	2.0	.8
3	-1.2	-2.2	-1.2	-2.2
4	-1.2	-3.1	-3.1	-1.2
5	0	-.1	0	-.1
6	-.5	-.8	-.8	-.5
7	-.3	.7	1.1	.7
8	-1.2	1.1	-.3	-1.2
9	-2.2	1.8	-2.2	-2.6
10	-2.6	.9	.9	1.8
11	3.3	.5	3.3	.5
12	2.2	1.6	1.6	2.2
13	.6	3.3	1.6	.6
14	1.6	2.4	3.3	2.4
15	.5	3.1	.5	3.1
16	2.8	-.1	-.1	2.8
17	3.1	-.7	3.1	0
18	0	0	0	-.7
19	-2.2	2.5	-2.2	2.2
20	2.2	-.8	-.8	2.5
21	1.0	1.8	1.0	1.6
22	1.6	3.2	3.2	1.8

Table 1

454 nm

	w & s	boston	ocusil	parperm
1	1.1	2.2	2.6	1.1
2	2.6	.9	2.2	.9
3	-1.0	-2.3	-1.0	-2.3
4	-1.0	-2.9	-2.9	-1.0
5	-.1	0	-.1	0
6	-1.4	-.6	-.6	-1.4
7	-.3	.4	1.2	.4
8	-1.2	1.2	-.3	-1.2
9	-2.4	2.0	-2.4	-2.7
10	-2.7	.9	.9	2.0
11	3.3	.6	3.3	.6
12	2.2	1.5	1.5	2.2
13	.7	3.3	1.7	.7
14	1.7	2.4	3.3	2.4
15	.5	3.3	.5	3.3
16	2.5	-.1	-.1	2.5
17	3.1	-.5	3.1	.2
18	.2	-.3	-.3	-.5
19	-1.9	2.7	-1.9	2.3
20	2.3	-.9	-.9	2.7
21	1.1	2.3	1.1	1.6
22	1.6	3.3	3.3	2.3

Table 2

536 nm

	w & s	boston	ocusil	paraperm
1	1.5	2.2	2.7	1.5
2	2.7	.9	2.2	.9
3	-1.3	-2.2	-1.3	-2.2
4	-1.3	-2.9	-2.9	-1.3
5	-.2	-.1	-.2	-.1
6	-1.6	-.7	-.7	-1.6
7	-.2	.2	1.2	.2
8	-1.2	1.2	-.2	-1.2
9	-2.4	2.2	-2.4	-2.8
10	-2.8	.9	.9	2.2
11	3.5	.7	3.5	.7
12	2.3	1.7	1.7	2.3
13	.6	3.4	1.7	.6
14	1.7	2.4	3.4	2.4
15	.7	3.4	.7	3.4
16	2.5	.1	.1	2.5
17	3.2	-.7	3.2	.1
18	.1	0	0	-.7
19	-1.7	2.5	-1.7	2.4
20	2.4	-.7	-.7	2.5
21	1.1	2.5	1.1	1.6
22	1.6	3.4	3.4	2.5

Table 3

618 nm

	w &s	boston	ocusil	paraperm
1	1.4	1.4	3.0	1.4
2	3.0	3.0	1.8	.7
3	-1.4	-2.2	-1.4	-2.2
4	-1.4	-2.8	-2.8	-1.4
5	-.2	-.2	-.2	-.2
6	-1.2	-.6	-.6	-1.2
7	-.2	.1	1.0	.1
8	-1.1	1.0	-.2	-1.1
9	-1.7	2.3	-1.7	-2.8
10	-2.8	.9	.9	2.3
11	3.3	.5	3.3	.5
12	2.5	1.6	1.6	2.5
13	.6	3.3	1.7	.6
14	1.7	2.5	3.3	2.5
15	.7	3.3	.7	3.3
16	2.5	0	0	2.5
17	3.0	-.8	3.0	.1
18	.1	-.1	-.1	-.8
19	-2.0	2.0	-2.0	2.2
20	2.2	-1.0	-1.0	2.0
21	1.1	2.4	1.1	1.5
22	1.5	3.3	3.3	2.4

Table 4

700 nm

	w & s	boston	ocusil	paraperm
1	1.6	1.6	2.7	1.6
2	2.7	1.0	1.6	1.0
3	-1.7	-2.0	-1.7	-2.0
4	-1.3	-2.3	-2.3	-1.3
5	-.2	-.2	-.2	-.2
6	-1.6	-.4	-.4	-1.6
7	0	.1	1.0	.1
8	-.9	1.0	0	-.9
9	-1.7	2.1	-1.7	-2.6
10	-2.6	.9	.9	2.1
11	3.4	.5	3.4	.5
12	1.3	1.7	1.7	1.3
13	.6	3.4	1.7	.6
14	1.7	2.4	3.4	2.4
15	.7	3.5	.7	3.5
16	2.2	.1	.1	2.2
17	3.0	-.5	3.0	-.1
18	-.1	-.1	-.1	-.5
19	-1.8	2.0	-1.8	2.0
20	2.0	-1.0	-1.0	2.0
21	1.2	2.2	1.2	1.6
22	1.6	3.4	3.4	2.2

Table 5

View of 372 nm

Paired t-Test X_1 : w & s Y_1 : boston

DF:	Mean X - Y:	Paired t value:	Prob. (2-tail):
21	-.318	-.624	.5393

1

Paired t-Test X_2 : ocusil Y_2 : paraperm

DF:	Mean X - Y:	Paired t value:	Prob. (2-tail):
21	-.109	-.267	.7921

2

Table 6

View of 454 nm

Paired t-Test X_1 : w & s Y_1 : boston

DF:	Mean X - Y:	Paired t value:	Prob. (2-tail):
21	-.386	-.746	.4639

1

Paired t-Test X_2 : ocusil Y_2 : parperm

DF:	Mean X - Y:	Paired t value:	Prob. (2-tail):
21	-.086	-.212	.8345

2

Table 7

View of 536 nm

Paired t-Test X_1: w & s Y_1: boston

DF:	Mean X - Y:	Paired t value:	Prob. (2-tail):
21	-.418	-.813	.4251

1

Paired t-Test X_2: ocusil Y_2: paraperm

DF:	Mean X - Y:	Paired t value:	Prob. (2-tail):
21	-.009	-.023	.9819

2

Table 8

View of 618 nm

Paired t-Test X_1: w &s Y_1: boston

DF:	Mean X - Y:	Paired t value:	Prob. (2-tail):
21	-.377	-.776	.4465

1

Paired t-Test X_2: ocusil Y_2: paraperm

DF:	Mean X - Y:	Paired t value:	Prob. (2-tail):
21	-.009	-.023	.9818

2

Table 9

View of 700 nm

Paired t-Test X_1: w & s Y_1: boston

DF:	Mean X - Y:	Paired t value:	Prob. (2-tail):
21	-.423	-.905	.3759

1

Paired t-Test X_2: ocusil Y_2: paraperm

DF:	Mean X - Y:	Paired t value:	Prob. (2-tail):
21	.077	.205	.8396

2

Table 10

totals of W & S vs. Boston

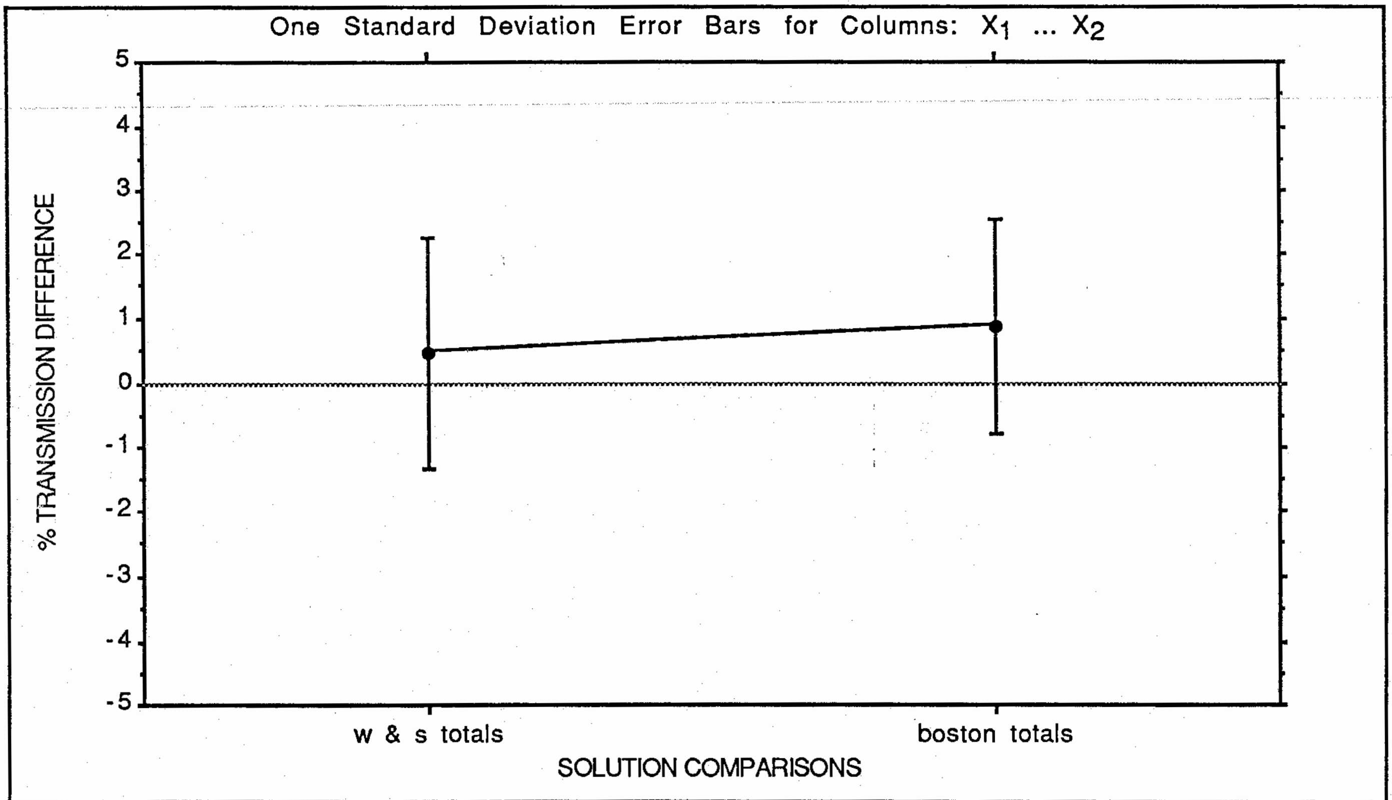

Figure 1

totals of ocusil vs. paraperm

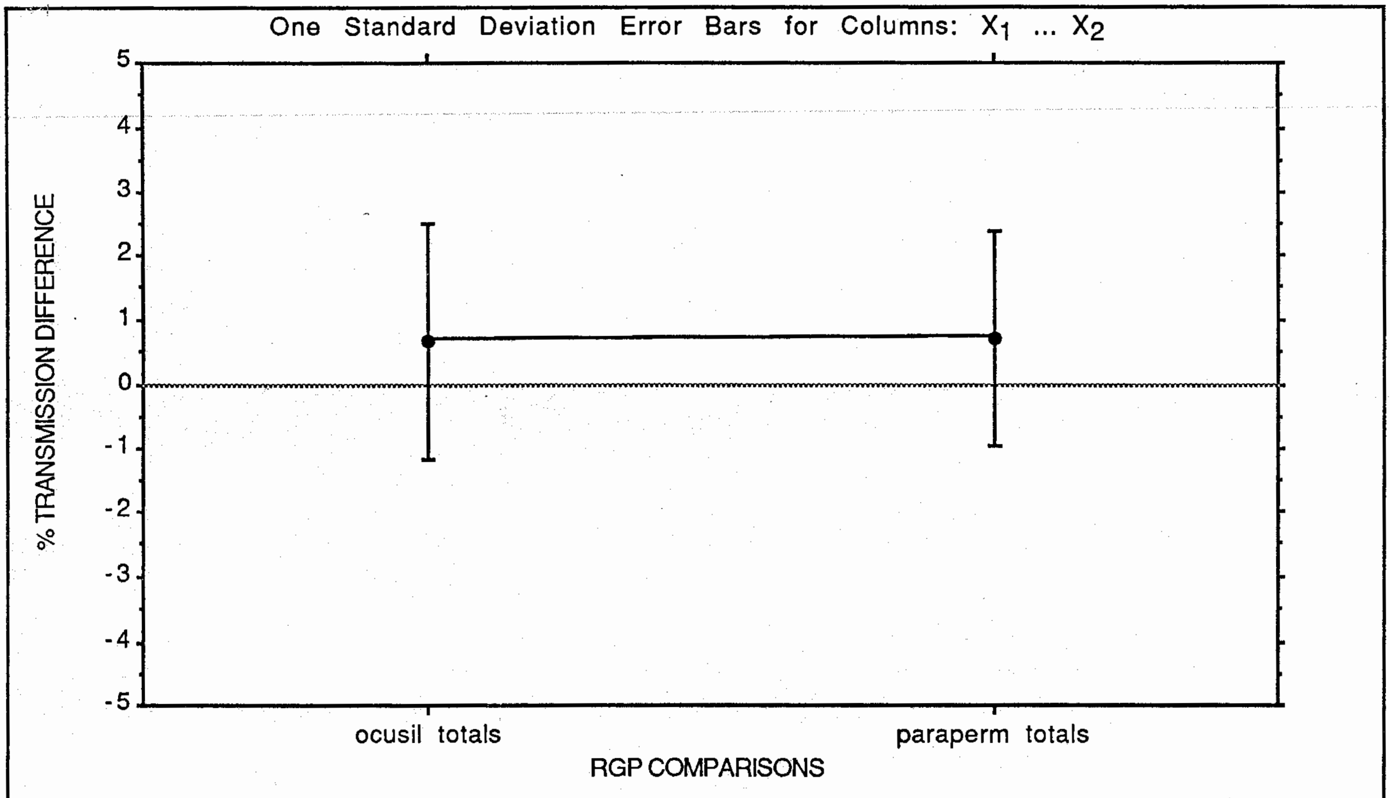

Figure 2

totals of W & S vs. Boston

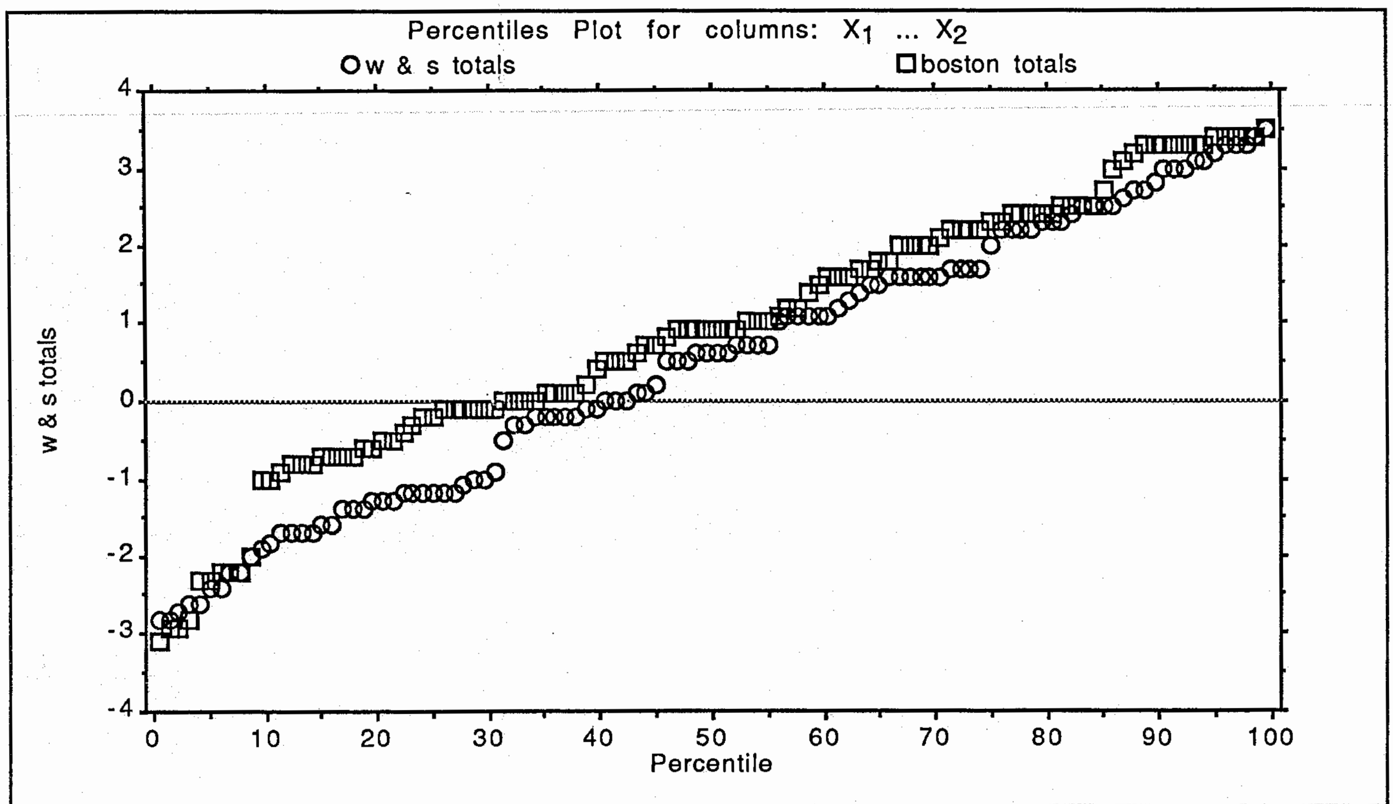

Figure 3

totals of ocusil vs. paraperm

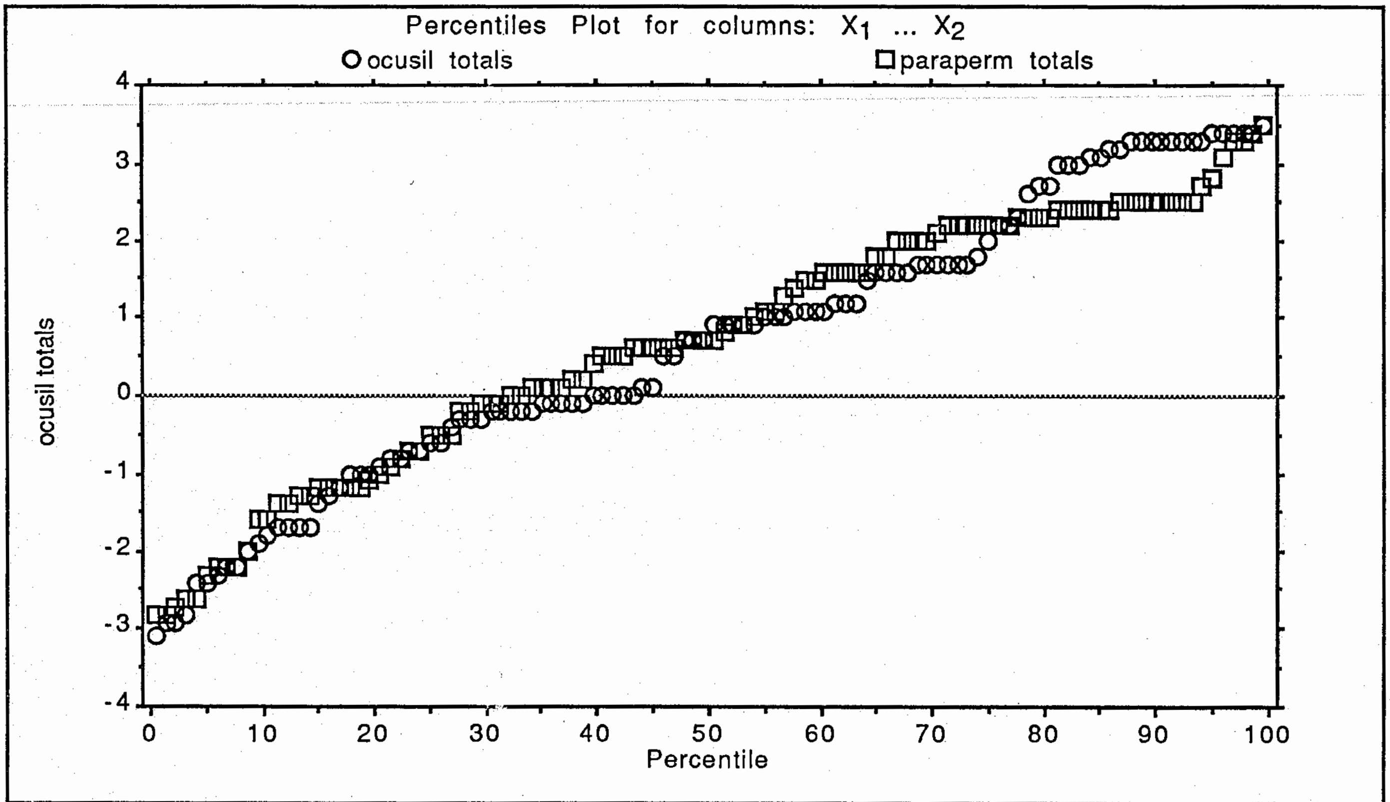

Figure 4